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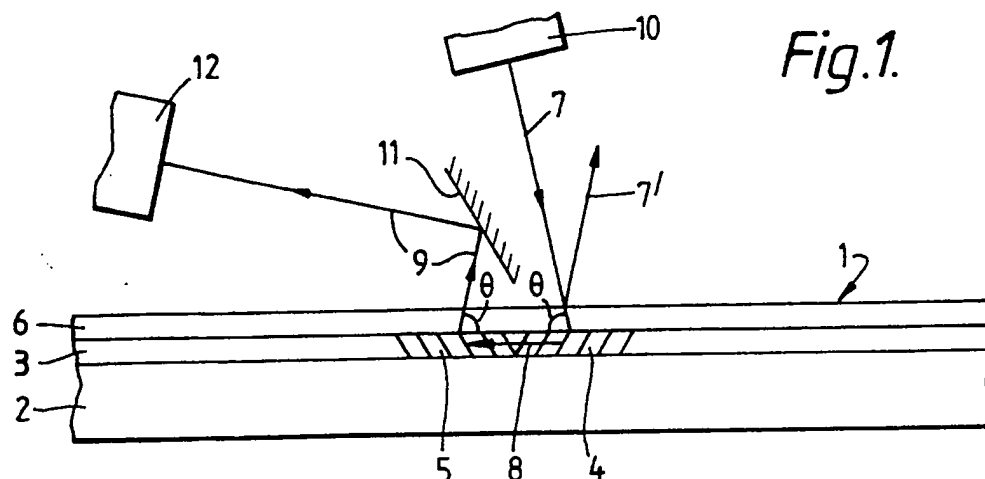
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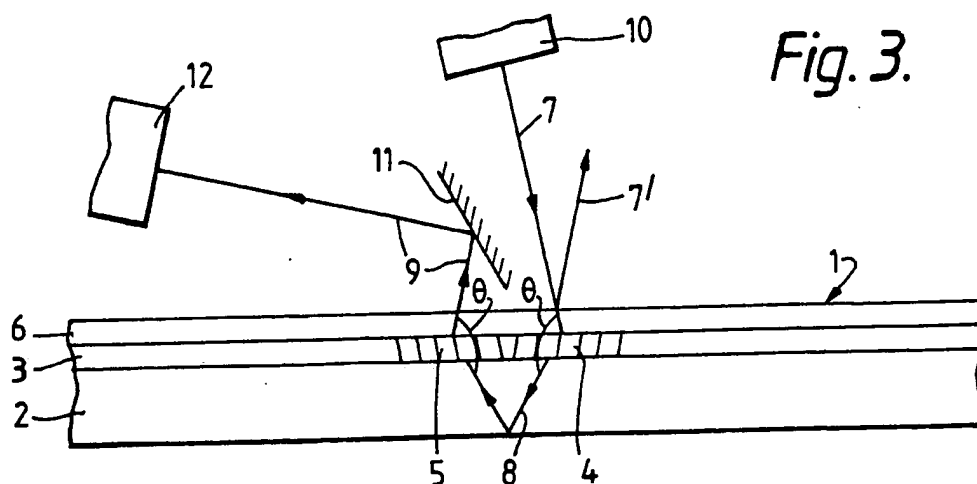
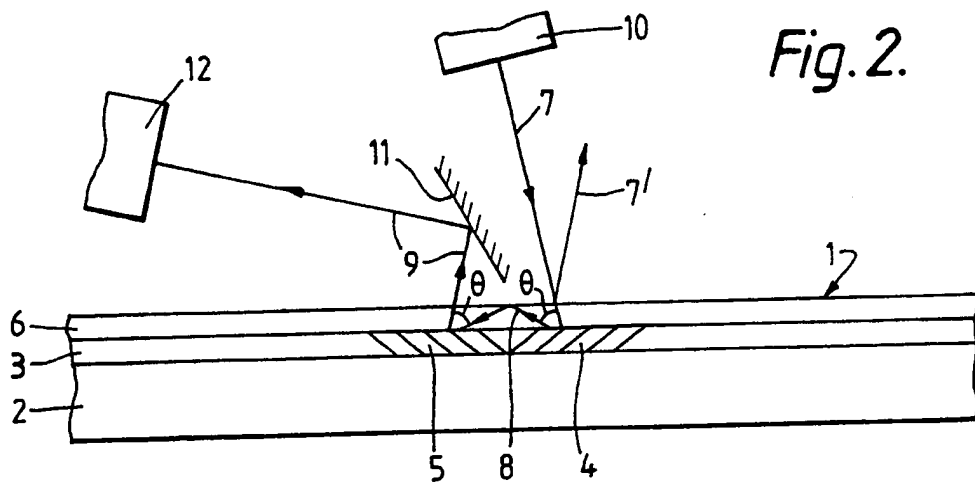
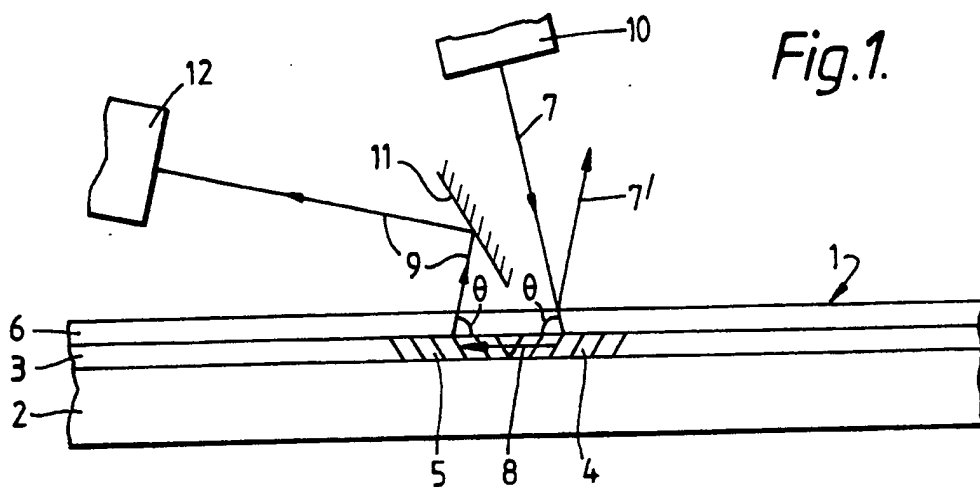
(54) **Data carriers**

(57) A carrier (1) bears data in the form of one or more optical microstructures (4/5) representing e.g. identification data on an access-control card or authentication data for documents or goods. Each microstructure comprises adjacent first (4) and second (5) elements of identical form, but arranged in a laterally inverted relationship, and located beneath a partially transparent and partially reflective surface (6) of the carrier. To read the data, light of a selected wavelength and incidence angle (7) is directed through the said surface (6) to the first optical element (4), which directs it through the structure of the carrier to the second optical element (5). The latter directs the light out of the carrier once more, in a direction (9) parallel to the direction (7) at which a proportion of the incident light is reflected at the surface (6) of the carrier, which makes it extremely difficult for an unauthorised person to discover the location and characteristics of the optical microstructure (4/5) by trial and error methods. In the proper reading apparatus for such carriers, a mirror (11) is correctly positioned close to the carrier surface to intercept the light emerging from the second optical element(s) (5) and so direct the same to an appropriate detector (12).

The optical structures may be solid holograms (Figs 1-3) diffractive structures (Fig 4) or reflectors (Fig 5); and the optical path therebetween may be direct (Fig 1) or may involve internal reflections from a surface of the carrier (Figs 2-5).



*Fig.1.*



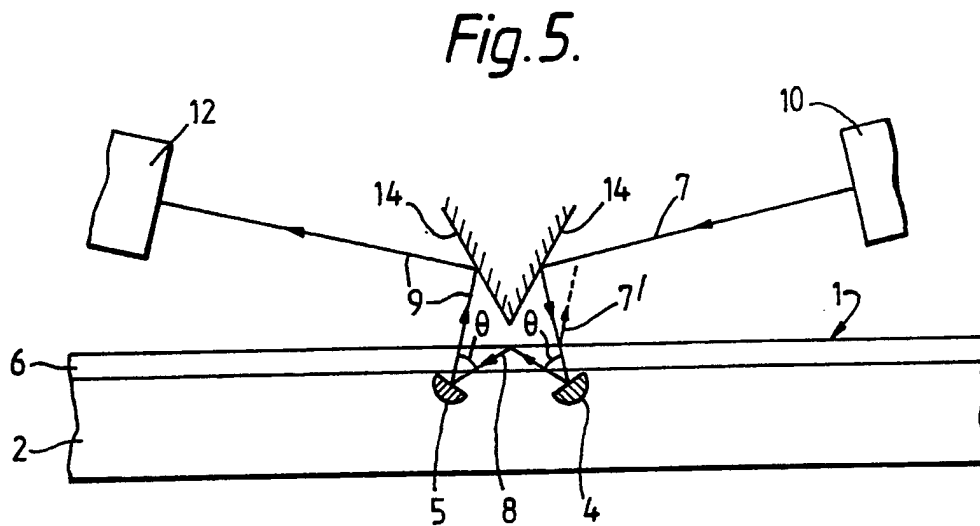
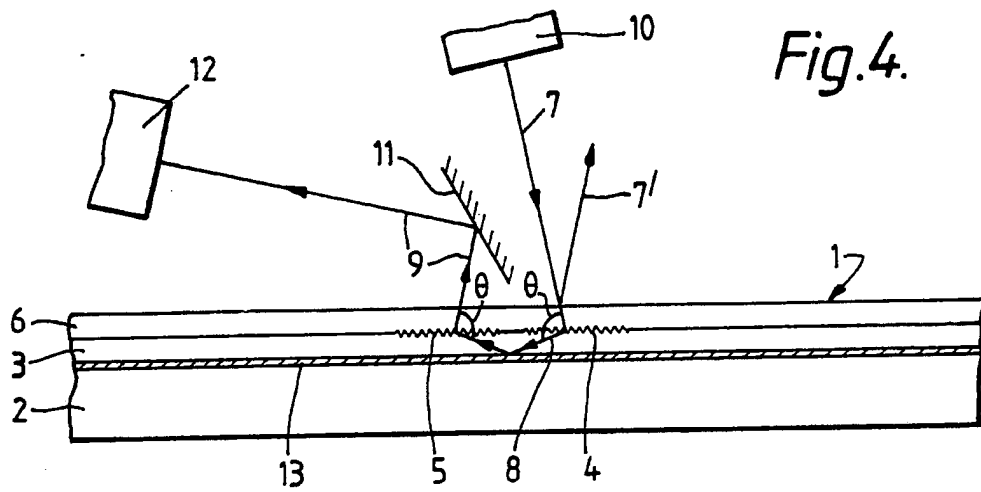


Fig. 7.

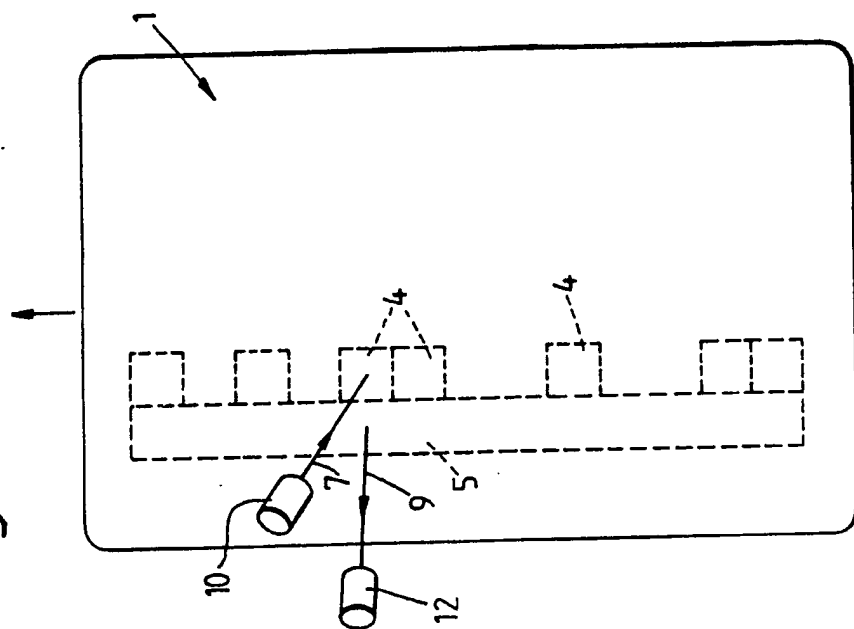
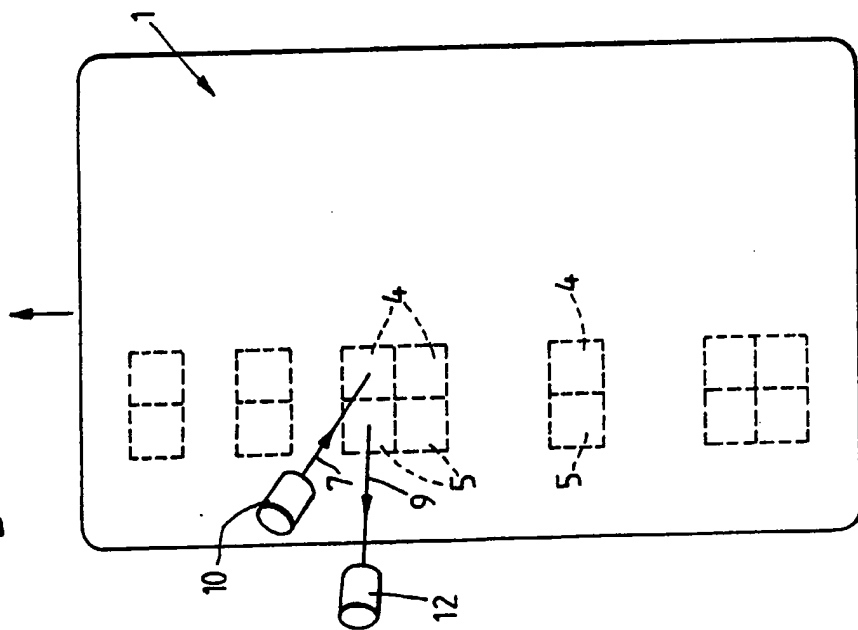


Fig. 6.



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### Data Carriers

The present invention relates to data carriers and to the storage of data represented therein by optical elements.

5 In particular the invention is concerned with the storage of data represented by means of holographic optical elements (hereinafter referred to as HOEs). By "holographic optical element" we mean a holographically-produced diffraction grating structure which is adapted to

10 reconstruct an output light beam in a specific direction by diffraction of incident light of a specific wavelength and incidence direction. However, it is also possible if desired to implement the invention through use of more classical, non-holographic reflective, diffractive or

15 refractive optical elements.

The invention is concerned in particular with the use of optical elements for security purposes, where they may be applied to, for example: access-control cards or the like

20 tokens, where they represent authorisation or identification data necessary e.g. for gaining access to a restricted area, operation of a cash-dispensing machine or the provision of some other service; documents such as credit cards, tickets, passports, licences, identity

25 cards, wills, cheques and the like, as a means of authenticating the same; and goods which are vulnerable to counterfeiting, for example audio/video tapes and discs and various other high-value consumer goods, again as a

means of distinguishing the genuine goods from unauthorised copies. Another potential field of use is where the optical elements represent units of value on a card or other carrier, relevant for purchasing goods from a vending machine or paying for time on a public telephone for example. However, this list of potential applications is not intended to be exhaustive and the term "data" as used herein is to be given its widest meaning. In a simple embodiment of the invention as defined below, this "data" may be represented merely by the presence of a single optical microstructure at a specified location on an article; in more complex embodiments there may be a multiplicity of such structures arranged in tracks or in other specified spatial relationships.

Data carriers of this general character are known e.g. from International patent application no. PCT/GB86/00109 (WO 86/05300) of K.J. Hayden, where data is represented by single or coded arrays of thick-film reflection HOEs and reading or recognition of the data is achieved by detection of light reflected in specific directions from the individual HOE(s) when they are illuminated at specific incidence angles. Another approach is shown in United States patent no. 4400616 to Chevillat et al where data is stored in a waveguide hologram within a carrier, which is adapted to be replayed onto a series of photodetectors by light coupled into the waveguide through a separate HOE. These known forms of data storage and read-out are in general more secure against fraudulent imitation or copying of the data than the more usual techniques for coding access-control cards and the like - such as magnetic stripes and printed bar-codes - but are certainly not immune. For example it would be possible to identify the locations and optical characteristics of the holograms on a card coded in accordance with the Hayden application or Chevillat patent by simple trial and error experimentation with various illumination and

viewing angles - achievable by eye in the the case of holograms replaying in visible light or with a suitable lamp and photodetector for those constructed to replay only in the infra-red or other non-visible band.

5

A solution to this problem is proposed in our copending United Kingdom patent application no. 8818418.9, where data is represented by HOEs which are adapted to couple light of a selected wavelength and incidence angle into  
10 (or out of) the structure of a carrier, that light being coupled out of (or into) the structure of the carrier through an element of selected refractive index placed into contact with an exposed surface thereof, and the transmission of light through the structure of the  
15 carrier between the HOEs and the index-matching element being by way of total internal reflection at said exposed surface. In this arrangement, therefore, the presence of the HOEs will remain undetectable by any external inspection which involves viewing (or illumination, as the  
20 case may be) of the external surface of the carrier through air.

The present invention seeks to provide an alternative solution to the above-discussed problem and accordingly in  
25 one aspect resides in a data carrier having at least in a region thereof an external surface which is partially reflective and partially transparent to light of a selected wavelength; the data carrier incorporating at least one optical microstructure which comprises adjacent  
30 first and second elements; said first element being adapted to direct to the second element (whether directly or indirectly through the structure of the data carrier) light of said selected wavelength which is incident thereto through said surface when directed to a first part  
35 of said surface from a first selected direction; and said second element being adapted to direct out of the data carrier through a second part of said surface adjacent to



said first part, in a second selected direction, light which is incident thereto from said first element as aforesaid; said second selected direction being generally parallel to the direction in which a portion of the light which is directed to said first part of said surface from said first direction is reflected at said surface.

An advantage of the above-defined arrangement, from the point of view of defeating attempts to discover the data represented by the optical microstructure on a data carrier otherwise than through use of the proper reading apparatus, is that when correctly illuminated to cause the second optical element to direct light out of the data carrier a reflection of the illuminating source will also be seen from the surface of the carrier directly adjacent to the position from where the "data" light emerges.

The optical characteristics of the data carrier surface - e.g. a smooth plastics card - and of the incorporated optical microstructure can readily be chosen so that the intensity of the surface-reflected light will be substantially greater than that which emerges from the second optical element. It follows that a person unaware of the position of the optical microstructure and tracking an illumination source around the exterior of the data carrier in the hope of discovering same will have the greatest difficulty in distinguishing the light emerging from the second optical element from the surface reflection which he is expecting to see - even if by chance he should at any one time arrive at both the correct illumination angle and the correct viewing angle for the optical microstructure.

Of course it must be possible to detect the light from the second optical element(s) of a data carrier as defined above in a bona fide reading apparatus. Accordingly, in a second aspect the invention resides in a reading apparatus for a data carrier according to the first-

mentioned aspect of the invention, comprising: at least one light emitter whereby said first part of said surface of a said data carrier can be illuminated with light of the said selected wavelength from the first said selected direction when the data carrier is received within the reading apparatus; at least one reflective element positioned within the reading apparatus such as to intercept light which is directed out of the data carrier through said second part of said surface in said second selected direction, but not to intercept the light which is reflected at said first part of said surface, when said first part is illuminated as aforesaid; and at least one light detector positioned within the reading apparatus to receive the light intercepted by said reflective element of the apparatus.

In the preferred arrangement of the data carrier, the first and second optical elements are substantially identical but arranged within the data carrier in a laterally inverted relationship, whereby to guarantee a parallel relationship between the emergent and surface-reflected beams. This will also ensure that any dispersive effects which may be exhibited by the first optical element (e.g. in the case of an embossed HOE or other relief structure) are compensated by the second optical element. Nevertheless, in certain embodiments some departure from a strictly parallel relationship may be tolerated, e.g. within 10° or so, provided that there is neither sufficient divergence between the beams to facilitate unauthorised detection of the optical microstructure nor sufficient convergence to render bona fide detection impractical.

Preferably the optical elements are themselves thick-film reflection HOEs, which can be produced with a high degree of selectivity to incident wavelengths and directions. In principle, however, it is possible to employ any kind

of optical elements having the ability to diffract,  
refract or reflect incident light for the defined  
purposes, including thick-film or embossed transmission  
HOEs; ruled diffraction gratings; refractive relief  
5 structures; or simple reflectors - such as shaped wire  
elements embedded within the data carrier. Transmission  
of the light from the first to the second optical element  
may be direct or indirect - e.g. by way of total internal  
reflection at an exposed surface of the carrier or  
10 reflection at an intermediate foil or other specular  
reflective surface.

It is to be understood that the use of the term "light"  
herein does not imply a limitation to electromagnetic  
15 radiation lying strictly within the visible spectrum and  
includes particularly radiation within the infra-red and  
untra-violet bands.

The invention will now be more particularly described, by  
20 way of example, with reference to the accompanying  
schematic drawings in which:-

Figures 1 to 5 are each cross-sections through various  
examples of access-control card embodying the invention,  
25 together with components of a reading apparatus therefor;  
and

Figures 6 and 7 are plan views indicating the positions of  
optical elements in further examples of the invention.

30 It is to be noted that the drawings are presented purely  
for the purpose of illustrating the principles of the  
invention and are not necessarily drawn to a true or  
consistent relative scale, nor do they necessarily depict  
35 true diffraction and reflection angles. In addition, the  
effects of refraction as respective light beams enter and  
leave the structure of the illustrated cards, or

traverse their layers, are omitted from the drawings. In all cases, however, the symmetry of the optical microstructures is such that these refractive effects will cancel out.

5

Like reference characters are used to denote elements of like function throughout the various figures.

10 With reference to Figure 1, this represents a cross-section through the thickness of a data carrier in the form of an access-control card 1. It comprises a laminate of three layers: a plastics substrate or supporting layer 2, an intermediate layer 3 supported thereby and bearing two HOEs 4 and 5, and a smooth  
15 protective plastics layer 6 over the top of the hologram layer 3. The material of layer 6 is both partially transparent and partially reflective to light of the wavelength required to replay the HOEs 4 and 5. The HOEs in this example are so-called thick-film, volume or Bragg-type reflection holograms each comprising a three-  
20 dimensional interference fringe pattern stored within the material comprising layer 3 - which may be e.g. silver halide emulsion, dichromated gelatin (DCG) or photopolymer. The HOEs are located closely adjacent and  
25 are of identical form but laterally inverted with respect to one another.

More particularly, the HOE 4 is constructed so that when illuminated with a light beam 7 of selected wavelength and  
30 incidence angle it reconstructs a beam 8 at an angle  $\theta$  to the incident beam such as to be aligned with the plane of the emulsion 3, and which is accordingly transmitted through that layer directly to the second HOE 5. The latter is likewise constructed so that when illuminated  
35 with the beam 8 it reconstructs a beam 9 at the same angle  $\theta$  to its incident beam, such as to be coupled out of the card structure in a direction parallel to the direction of

direct reflection 7' of the first incident beam 7 at the card surface; (as previously indicated, the drawing does not show the effects of refraction as the beams 7/9 enter/exit the card but the corresponding angular shifts will cancel out). It is arranged, by appropriate selection of the material for surface layer 6 and bearing in mind the inherent losses in the reconstruction of beams 8 and 9, that the intensity of the emergent beam 9 is significantly less than that of the surface-reflection beam 7', which taken together with the parallel and closely-adjacent relationship of these two beams makes it extremely difficult to identify the beam 9 without a proper reading apparatus, as previously explained.

The purpose of the HOEs 4 and 5 in the access-control card as illustrated in Figure 1 is to verify that card as an authentic token e.g. for gaining access to a restricted area etc. as indicated in the preamble of this specification. For this purpose, in use of the card it is presented to a reading apparatus which senses the presence of the reconstruction beam 9 transmitted away from the second HOE 5 in the selected direction when the first HOE 4 is illuminated with an appropriate incident or replay beam 7.

A reading apparatus for such a card will therefore include, as also indicated in Figure 1, a light source 10, such as a light-emitting diode (LED), positioned to illuminate the HOE 4 at the requisite angle to produce the first reconstruction beam 8, and a mirror 11 positioned closely to the card to intercept the beam 9 emerging from the HOE 5 (but not the beam 7') and to direct it to an appropriately-positioned light detector 12, such as a photo-diode. In this respect it will be understood that the light source 10, mirror 11 and light detector 12 will all be located at specified positions in relation to a card slot which defines the orientation of the card when

it is located in, or passed through, the reading apparatus, so that light can be transmitted from the source 10 to the detector 12 only when a card bearing two HOEs 4 and 5 of the correct characteristics at the correct locations on the card is presented to the apparatus. To prevent spoofing the apparatus simply by flooding it with light there will preferably also be one or more further, reference detectors (not shown) located to detect light from positions on the card where none should be directed from the HOE 5; the associated logic will be arranged to accept the card as authentic only when the output of the primary detector 12 is above a certain threshold while the output(s) of the reference detector(s) are below a certain threshold.

Although Figure 1 illustrates the most direct method of transmitting the light coupled into the card from HOE 4 to HOE 5, in practice it may be difficult to manufacture a card with such critically-defined tolerances as to ensure direct transmission along the emulsion layer, and Figure 2 illustrates an alternative scheme which may be considerably more amenable to serial production. In this case the beam 8 reconstructed from the HOE 4 is directed back towards the surface of the card but its reflection angle  $\theta$  is so chosen, having regard to the refractive index of the material selected for layer 6, that it is incident to the plastics/air interface at that surface of the card at an angle above the so-called critical angle (as measured with respect to the normal to that surface) so that total internal reflection occurs at that interface. The characteristics of the HOE 5 are again such as to reconstruct a beam 9 at the same angle  $\theta$  to the beam 8, which is incident thereto from the surface of the card, whereby the beam 9 is coupled out of the card in parallel to the surface-reflection beam 7'.

In the variant of Figure 3, the optical elements 4 and 5

are instead thick-film transmission HOEs and the beam 8 is transmitted from 4 to 5 by total internal reflection at the plastics/air interface at the exposed surface of the supporting layer 2 at the opposite side of the card from the emitter 10.

In the variant of Figure 4, the optical elements 4 and 5 are instead embossed transmission HOEs and the beam 8 is transmitted from 4 to 5 by reflection at the surface of an additional metal foil 13 laminated with the card.

In the variant of Figure 5, the optical elements 4 and 5 are instead specular reflectors formed from pieces of shaped wire embedded in the card structure, and the beam 8 is reflected from 4 to 5 via the plastics/air interface at the surface of layer 6 similarly to the embodiment of Figure 2. Figure 5 also shows a rearrangement of the reading apparatus - which may equally be used with the other card embodiments - where there is a double-faceted mirror 14 one facet of which directs the incident beam 7 from the emitter 10 to the element 4 and the other facet of which directs the emergent beam 9 from the element 5 to the detector 12.

As so far described, there is only a single micro-structure, comprising the pair of optical elements 4 and 5, to be detected on a card, representing a single bit of data. This may be sufficient for some authentication purposes but for higher-security applications there will generally be a multiplicity of such microstructures, which can represent multi-bit access or identification codes, and which makes forgery very much more difficult.

One such arrangement is shown in Figure 6. In this example there is a plurality of microstructures 4/5 in a track along a card of which the elements 4 are illuminated serially by the beam 7 from light source 10 as the card is

passed through the reading apparatus. The reconstructed beams from the elements 4 illuminate in turn the associated elements 5, to produce in turn corresponding output beams 9 directed to the detector 12; (the mirror 11 or 14 is, for clarity, omitted from this Figure). The output level of the detector 12 at any instant will therefore signal the presence or absence of a structure 4/5 in the path of light source 10 and the distribution of these structures and intervening spaces on different cards thus represents individual digitally-coded data. It will be appreciated that an equivalent effect can in fact be achieved by providing a coded track of input elements 4 with a continuous output-element 5 as shown in Figure 7, or vice versa, which may have certain advantages in production.

It should be noted with reference to Figures 6 and 7 that the size of the elements 4 and 5 shown therein has been greatly exaggerated in order to illustrate the operating principles of the cards. In practice such elements may be produced with a characteristic dimension in the order of 0.5mm across, meaning that a track of 150 or so data bits could be incorporated within standard credit card dimensions.

In practice all of the embodiments of the invention described herein will operate with input and output light beams 7/9 in the infra-red band, which has advantages in discriminating the beams 9 from ambient light when reading data from the cards and means that the external layers 2 and 6 of the cards can be made from visibly-opaque (though IR-transparent) plastics.



CLAIMS

1. A data carrier having at least in a region thereof an external surface which is partially reflective and  
5 partially transparent to light of a selected wavelength; the data carrier incorporating at least one optical microstructure which comprises adjacent first and second elements; said first element being adapted to direct to the second element light of said selected wavelength which  
10 is incident thereto through said surface when directed to a first part of said surface from a first selected direction; and said second element being adapted to direct out of the data carrier through a second part of said surface adjacent to said first part, in a second  
15 selected direction, light which is incident thereto from said first element as aforesaid; said second selected direction being generally parallel to the direction in which a portion of the light which is directed to said first part of said surface from said first direction is  
20 reflected at said surface.

2. A data carrier according to claim 1 wherein the first and second optical elements are substantially identical but arranged within the data carrier in a laterally  
25 inverted relationship.

3. A data carrier according to claim 1 or claim 2 wherein the first optical element is adapted to direct light directly through the structure of the data carrier  
30 to the second optical element.

4. A data carrier according to claim 1 or claim 2 wherein the first optical element is a reflective element and is adapted to direct light to the second optical  
35 element by way of total internal reflection at the exposed surface of the data carrier on that side thereof which faces the incident light.

5. A data carrier according to claim 1 or claim 2 wherein the first optical element is a transmissive element and is adapted to direct light to the second optical element by way of total internal reflection at the exposed surface of the data carrier on that side thereof which is remote from the incident light.

6. A data carrier according to claim 1 or claim 2 comprising also means providing a specular reflective surface located on that side of the optical microstructure which is remote from the incident light and wherein the first optical element is a transmissive element and is adapted to direct light to the second optical element by way of reflection at said specular reflective surface.

7. A data carrier according to any preceding claim wherein said optical elements are selected from the group comprising thick-film holographic optical elements, embossed holographic elements and specular reflective optical elements.

8. A data carrier according to any preceding claim comprising a plurality of said optical microstructures disposed in a coded track, the said first optical element of each said microstructure being adapted to direct to the respective said second optical element light of the same selected wavelength which is incident thereto from the same selected direction.

9. A data carrier according to claim 8 wherein the first or second only of said optical elements in each said microstructure is constituted by a respective part of a continuous optical element extending along said track.

10. A data carrier according to claim 1 and substantially as hereinbefore described with reference to the accompanying drawings.

11. A reading apparatus for a data carrier according to claim 1, said reading apparatus comprising: at least one light emitter whereby said first part of said surface of a said data carrier can be illuminated with light of the said selected wavelength from the first said selected direction when the data carrier is received within the reading apparatus; at least one reflective element positioned within the reading apparatus such as to intercept light which is directed out of the data carrier through said second part of said surface in said second selected direction, but not to intercept the light which is reflected at said first part of said surface, when said first part is illuminated as aforesaid; and at least one light detector positioned within the reading apparatus to receive the light intercepted by said reflective element of the apparatus.

12. A reading apparatus according to claim 11 and substantially as hereinbefore described with reference to the accompanying drawings.